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STUDY THE EFFECT OF RECYCLED GLASS POWDER IN COMBINATION WITH CORN STARCH AS A BINDING AGENT – "A SUSTAINABLE APPROACH TOWARDS RE-EVALUATING THE MECHANICAL PROPERTIES OF GLASS CONCRETE"

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ABSTRACT

Concrete is a versatile building material which is utilized in maximum construction activities. Extensive deterioration might encounter in concrete due to abrupt environmental changes, but fibrous concrete can potentially enhance the value and scaleof concrete, which can substantially play significant role inhumid environments. Concrete is consumed exponentially in execution works with inevitably increasing consumption. It has to encounter multi-dimensional environmental issues like blistering and scaling. Some fibers if added can substantially improve the voids ratio in fibrous concrete. Keeping in view, sodium silicate glass (SSG) might be considered substitutefor cement. It can be utilized with different percentages 0%,5%,10% and 15%as a replacement cement in combination with corn starch(CS), which should be 1% for all mixes. In this paper, an experimental study is conductedto investigate the classified properties of concrete,by performing wide range of testing procedures that includes, compression test, split tensile test, alkali silica reactivity test, sulfate resistivity test and drying shrinkagetest. In this connection, ninety-sixconcrete cylinderswere prepared for compression and split tensile test, forty-eightconcrete cubes for compression test and thirty-six mortar bars of four mixes are prepared for durability testing. Freshly prepared concrete was tested and checked for workabilityduring the pouring of concrete cylinders. Poured cylinders' samples are left for different age-based testing of curing to be conductedat 7,14,21 and 28 days respectively. After curing, samples are tested to check the compressive strength of hardened concrete. Workability of four mixes lies between 50-70mm. Test resultsshowed that compressive strength of concrete is increased using SSG of15% as compared to other mixes of concrete with 5% and 10%, inferring thatfibrous concrete is suitable for humid environments, where high strength and concrete with minimum voidsis required. In addition to that, the glass powder if added cautiously can predominantly improves the strength of concrete ultimately helps inreduction of water cement ratio. As per the recommendations of the research, if the cement's quantity is reduced drastically and instead of cement then recycled glass powder is added to concrete at least 15% for quantities included in overall concrete mixture to attain optimum results.

INTRODUCTION

Concrete is a composite building construction material which is used in construction industry. Consumption of concrete is now increasing day by day(Sharma & Sangamnerkar, 2015). It is the 2nd largest building material which is mostly used in construction industry. Many environmental issues producing by the use of concrete which are never be neglected and needed to be taken under consideration. A lot more natural resources are used for the production of concrete as fine and coarse aggregates(Singh et al., 2015),(Jiang et al., 2022).

Approximately one-tonquantity of carbon dioxide is discharged into the atmosphere by production of one ton of cement. It is 7% of the world's total annually production of CO2. Now It is our duty to save the natural resources for next generation and relieve the burden from the environment for ecological balance(Islam et al., 2017),(Solihu & Abdulkadir, 2022).In Pakistan it is time to find out the residue to save the environment and fulfill the construction needed without disturbing the natural resources(Wang et al., 2022),(Ashiq et al., 2022). This can be only achieving by using waste material in our surrounding like waste glass powder, fly ash, coconut fiber, plastic etc. The

use of waste materials in concrete will reduce the economic factor in major construction projects(Venkatraman & Sathish Kumar, N.D.),(Zidol et al., 2017).

Concreteisamixtureofcement, fine and coarse aggregatehaving properties like compressive strength, tensile strength, workability, durability(Ayat et al., 2022).When the cement mix with water it takes chemical reaction due to which heat generated and hardened(Derinpinar et al., 2022). The initial setting time of cement starts within a few minutes. It takes some weeks to gain full strength and continue to gain strength over many years(Omran & Tagnit-Hamou, 2016),(Raju & Kumar, 2014).

Corn is widely cultivated around the world, and large amounts of Corn are grown each year (Figure 1). According to the 2013 International Grains Council, total world production was 1.04 billion tonnes. Corn is one of the most important grains in America. The country produced 361 million tons of Corn in 2014. In recent years, the annual income of corn farmers has increased steadily. In 2016/17, the United States supplied over 33% of total corn production.

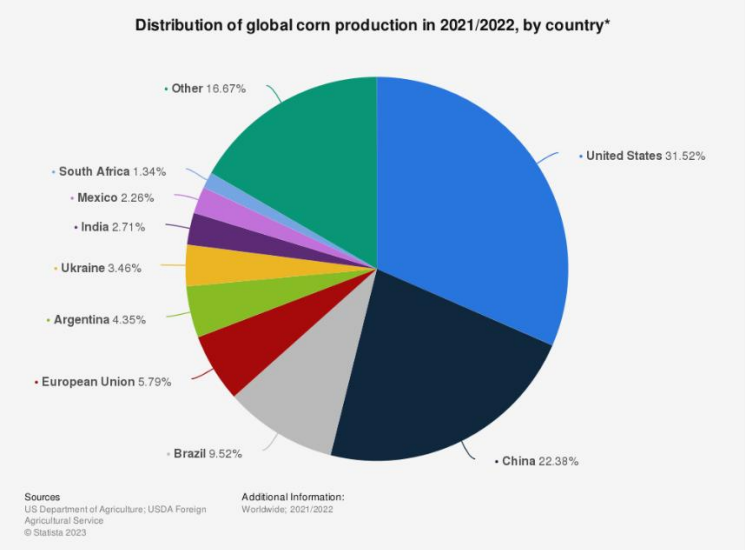

Fig. 1: Corn production worldwide

Recycled glass powder in cement will increase the strength properties due to the reaction of alkali with the cement. It helps the manufacturing process of bricks and it can be preserved as a raw material(Du & Tan, 2014),(Orouji et al., 2021),(Tho-In et al., 2018). Waste materials can be used after recycling. Waste materials like fly ash, coconut fiber, steel fiber and glass powder are used in different forms of construction materials after recycling.

When cement is replaced with glass powder it gives better workability and also in higher strength for concrete(Hendi et al., 2019). To achieve the sustainable environment, a necessary action are needed to clean environment and atmosphere and introduce the alternative of cement(Patel et al., 2019).

The usage of waste glass in concrete will increase the alkali content in the cement. Recycling ratio of this mix is close to 100%, and it is also used in concrete to improve the durability properties of concrete(Du & Tan, 2017).Recently, glass and its powder have been used as a building material in different structural applications like beams(Onaizi et al., 2022). Also the major benefit is to reduce the environmental problems which leads to sustainable construction. Hence, glass powder is abundantly used as a replacement of supplementary cementitious materials(Aliabdo et al., 2016).

MATERIALS:

Ingredients of concrete consist of cement,sand and crush. When water is mixes with cement then chemical reaction starts as a result heat is produced. This heat directly effects on the strength property of concrete.

- Best way cement is used for this study to prepare a concrete.

- Chenab sand and margala crush are collected from a single vendor for the preparation of concrete.

- Corn starch(CS), maize starch, or cornflour is the starch derived from corn (maize) grain. The starch is obtained from the endosperm of the kernel. Corn starch is a common food ingredient, often used to thicken sauces or soups, and to make corn syrup and other sugars. Cornstarch is a popular additive for thickening, suspending and stabilizing.

- Glass bottles have been collected and then finely ground for processing. It is a non bio-degradeable material and difficult to decompose. Utilization in concrete as a replacement of cement may leads to cost-effective resource. Glass powder after recycling and convert into powdered form and powdered corn starchshown in **fig. 1.**

(a) (b)

Fig. 1: Cementitious material: (a) Glass Powder(SSG), (b) Corn Starch(CS)

As cement is ultra-fine material like both glass powder and corn starch are used in this study as a replacement of cement. Chemical composition of cement and glass powder is given in **Table 1.**

Table 1: Chemical composition of glass and cement

Composition	**Cement(%)**	**Glass Powder(%)**
SiO_2	21.2	70.0
Al_2O_3	4.5	2.1
CaO	61.7	7.10
Na_2O	0.18	7.8
K_2O	0.80	0.81
Fe_2O_3	3.2	2.43
MgO	1.8	1.1
SO_3	2.5	0.1
TiO_2	--	0.13
Other	1.6	1.0

METHODOLOGY

Mix Design:

1:2:4. ratio is used for all mixes, One part of cement, two part of sand, and third part of aggregate by weight. Water cement ratio is used for this mix is 0.50. (Osarenmwinda & Awaro, 2009)

In this study, colored raw glass powder has been used as a partial replacement of cement. All ingredients of concrete are used in appropriate proportion. Also, the cement is replaced with glass powder at different percentages 0%, 5%, 10%, and 15% by glass powder in combination with corn starch 1%for all mixes. Research objectives of this study are to evaluate the effect of waste glass powder (SSG) in combination with corn starchon workability, compressive strength, alkali silica resistivity test, Sulfate Attack and drying Shrinkage of concrete specimens. Mixing of concrete is done with mixer as shown in **Figure 2.**

Fig. 2: Mixing of concrete

Sample Preparation:

Ninety-six concrete cylinders (150mmx300mm)6"x12", forty-eight concrete cubes (50mmx50mm) 2"x2", thirty-six mortar bars (40mmx40mmx160mm) of

four mixes (M1, M2, M3 and M4) are prepared by adding glass powder with different percentages of 0%, 5%, 10% and 15% and 1% corn starch as replacement ofcement as shown in **Figure 3** and hardened concrete cylinders, mortar cubes and beams as shown in **Figure 4**. Mix proportion 1:2:4 and W/C ratio 0.5 is same for all mixes with different curing days7, 14, 21, 28.

Fig.3: Casting of concrete cylinders, cubes and mortar bars

Casting and Curing:

After measuring the workability of concrete, casting is done of four mixes as per the designed percentages. Ninety-six cylinders (96 cylinders) were casted according to (ASTM C-192) and cured at 7, 14, 21 and 28 days. After curing test, the samples (cylinders) at curing ages 7,14,21, and 28days.

Few tests are performed on fresh and hardened concrete on different samples.

Fig. 4: After casting hardened concrete cylinders, cubes and mortar bars

Slump Test:

Slump Test is performed on fresh concrete to measure the workability of four mixes M1, M2, M3 and M4. In order to check the water cement ratio and required quantity of water in concrete to make it workable. This test is performed on fresh concrete according to ASTM C 143(Safiuddin et al., 2011). Measuring of slump as shown in **Figure 5**.

Fig. 5: Measurement of slump on fresh concrete

Compression Test:

The maximum reliability of concrete is a compression test which is performed on hardened concrete samples(Safiuddin & Hearn, 2005). In this research, total of four groups of concrete mixes areprepared in laboratory. The replacement level of cement to glass powder is used for different mix 0%, 5%, 10%, and 15% in concrete to check the result compressive strength in compression testing machine as shown in **Figure 6.**

(a) (b)

(c)

Fig. 6: Experimental setup (a) Compression Testing Machine (b) sample before testing & (c) sample after testing

Flexural Test:

Flexural test is performed to evaluate the crack resistance. It is related with the initial stage of cracks. Flexural test is carried out on prisms to evaluate the strength of concrete according to ASTM C78(Jalil et al., 2019). Prisms are

firstly casted at all replacement levels and then cured to check at 28days. Mortar bars are placed in machine horizontally as shown in **Figure 7.**

(a) (b)

Fig. 7: Experimental setup: (a)Sample (mortar bar) before testing& (b) after testing

Alkali Silica Reactivity Test:

The alkali-silica reactivity test is the chemical reaction that takes place between hydroxyl ions and alkali cations in solutions hydrated with cement paste and reactive silica in aggregates used in concrete. This test evaluates the length change due to swelling of a concrete sample. ASR test performed on mortar bars.

Sulfate Resistivity Test:

Sulfate attack on concrete was evaluated for strength loss, swelling, cracking and concrete collapse. These include salt crystallization due to salt damage, and sulfate present in soil, seawater, or groundwater due to chemical attack.

Drying Shrinkage Test:

A drying shrinkage test is performed to measure the dimensional change of the sample. Figure 8 shows the length measurement results.

Fig. 8: Measurement of change in length of mortar bar

RESULTS AND DISCUSSIONS

Results of fresh and hardened specimens of concrete have been discussed.

Slump Test Results:

Workability of concrete increases as the powdered glass content increased. There is a systematic increase from 50mm (for control mix) to 75mm (at 15% replacement).

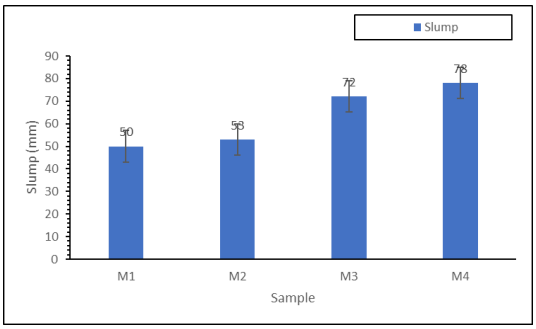

Fig. 9: Slump at Different Percentage of Glass powder and Xanthan Gum

Figure 9 shows the result of slump at different percentage levels. This graph shows that workability of fresh concrete increases by adding the glass powder in addition to corn starch. This increase may be the use of glass powder (SSG) in addition plastic property.

Compression Test Results:

After the slump test, the fresh concrete specimens poured into cleaned and well-oiled concrete cylinders and left for 24 hours to set. The hardened concrete remolded off the cylinder and cured for 7, 14, 21 and 28 days inside a curing tank by complete immersion in water.

Figure 10 shows the graphical representation of compressive strength of concrete cylinders on 7, 14, 21 and 28 days. Strength increases by adding the glass powder.

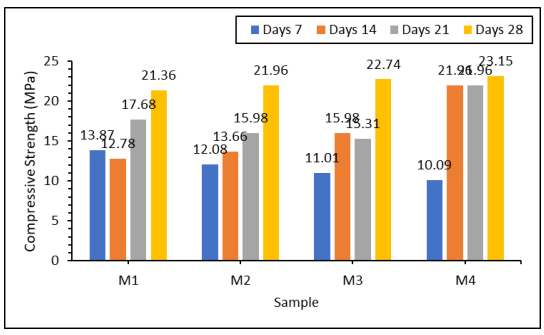

Fig. 10: Summary of compressive Strength of concrete cylinders of all mixes

This graph shows that compressive strength of concrete cubes with different replacement level of glass powder. Strength of concrete cube increases and makes concrete durable as compared to conventional concrete but the strength of 28 days nearly equal to conventional concrete.Also bonding properties are improved by adding corn starch and reduced voids.

Flexural Test Results:

Increases the content of sodium silicate glass (SSG) increases the flexural strength at 28 days as shown in Figure 11 The max.Strength increases at 15%replacement level is 15% i.e. 11%. SSG powder increased the flexural and tensile strength.

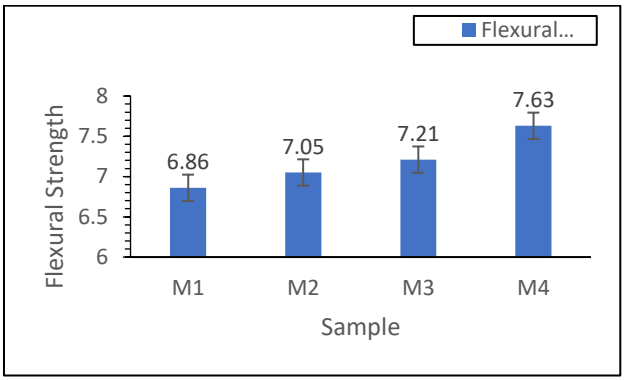

Fig.11: Flexural strength of concrete cubes calculated on 28 Days timespan

Permeability & Durability:

For better performance of concrete durability and perm- ability, few test alkali silica reactivity test, sulfate resistivitytest and drying shrinkage test are performed. Results are shown in Figure 12. Concrete is more resistant by adding glass powder with corn starch.

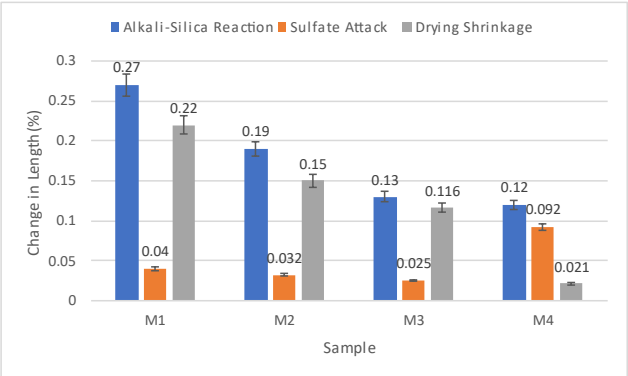

Fig. 12: Percentage change in length due to expansions Caused by Alkali silica reaction, Sulfate Attacks and Shrinkage by Drying

Mechanism and analysis of Glass Concrete by ASR:

ASR normally happens with aggregate reaction When concrete have the reactive aggregates and both have pozzolanic property then ASR may occur. CSH gel is produced in dense concrete (formula 1). When ASR happens, loose gel of ASR is produced. ASR is similar to pozzolanic reaction but k^+ and Na^+ are replaced with Ca^{+2}(formula 2). These two reactions are correlate with each other. Large amount of SiO2 present in cement may react with Na+, K^+ and OH- in concrete in response loose ASR gel formed.

$SiO_{2+} 2OH^{-}+ Ca^{+2}n_1\ CaO . SiO2 . n_2\ H_2O$……..(1)

$SiO_{2+} 2OH^{-} + 2Na^{+}\ (K^{+})\ Na_2(K_2) . SiO_{3\ .}\ H_2O$……(2)

After that ASR gel absorbed water and swelled then expansion rate increases. When glass particles size are less than pozzolanic activity of glass powder are activated when used as cementing material. Active ingredient SiO_2 in glass powder may involve in reaction, consuming $Ca(OH)_2$ in large amount and formed a dense CSH gel. OH- ions used in large amount in solution. Due to the ASR activity in concrete, OH- ions may reduce. On the other side, ASR gel prevent the swelling. CSH gel have a durable and strong sustainable activity which eliminates and reduces the concentration of Na^+ ions in solution in response decreases the alkali silica reaction degree of active aggregates. As shown in equation 1and 2.

Environmental and Financial Considerations:

WasteGlass generate in a huge quantity and it's a non-biodegradable material. As it's an environmental burden and difficult to decompose. Need to use in a productive way after recycling. By the use of waste glass in powdered form after recycling as a construction material, improve the aesthetic and strength properties. Glass powder also a cost-effective material.

CONCLUSIONS

Conclusions have been extracted from experimental results.

- Workability of normal concrete increases with the percentage increase of SSG. Slump at 15% is 78mm by 56%. All mixes have achieved the required workability between 50mm to 80mm that issuitable for the use of normal concrete.

- Compressive strength of concrete increases by the addition of raw glass powder. Max. strength is achieved by 15% replacement of waste glass powder in concrete which will increases the compressive strength by 8.3% in 28 days and min. strength is increased around 3%. Moreover, Flexural strength of glass concrete increases slightly (11% at 15% SSG)

- An SSG powder reduces the permeability and improves the durability properties. SSG powder may contain organic minerals, which stabilize the strength property and have no adverse effect on the strength of concrete. Also all concrete mixture has achieved the desired strength (25MPa).

- By the use of (SSG) raw glass powder can save the resources, cost, energy and environmental pollution.

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SUMMARY

Strength of glassconcrete M1, M2, M3 and M4 are not significantly changed; Moreover, glass concrete is strong, durable and more water resistant. Also, it has better insulation and sulfate resistance. Glass powder can be utilized for mixing of concrete without any strength loss. Glass powderis recommended to be used in the construction industry at 15% replacement for mixing of normal and aesthetic concrete

CONFLICT OF INTEREST

All the authors and sourcesare confirmed not to have any conflict of interest.

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